Committee Report for the MECO Magnet System Interim Design Review

September 24, 2001

Committee:
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The MECO Interim Review of the MIT/PSFC Magnet System Design Study was held at Brookhaven National Laboratory on September 10-11, 2001. This meeting had three purposes as defined by the Charge to the Committee.

• Review the status of the MIT/PSFC conceptual design study of the MECO magnet system.

• Review the structure for the interaction between the MECO Collaboration, BNL, and the Magnet Design Group to determine if it is appropriately set up and working.

• Consider the various MECO procurement strategies and comment on their appropriateness for the project.

1. Status of Conceptual Design Study

Overall the committee was impressed with the amount of progress that was made on the conceptual design study, particularly given the short time since the initiation of effort. Although there are a number of technical issues yet to be resolved, the committee could not identify any "show stopper" issues that might jeopardize the project. Given sufficient time and resources, the committee believes that the MECO magnet system could be successfully built, installed and operated at BNL. Of course, there is a lot of work needed between now and the first experiments with MECO.

During the one-day technical presentations, the committee received presentations on the magnet system design, conductor design, structural analysis, cryogenic system and assembly procedure. To date, more progress has been achieved on the Production Solenoid (PS) and Transport Solenoid (TS) than the Detector Solenoid (DS) since the former represent larger engineering challenges. Below are the committee's responses to the specific charge:

a. Design techniques and analysis tools. The electromagnetic analysis of the MECO magnet system is appropriate for the CDR and nearly complete. One remaining issue is the effect of iron shielding, but this appears to not be a major issue. Also, the coil performance analysis including quench is complete based on the assumed parameters. This work uses codes developed by the MIT/PFSC team. The structural analysis approach is based on ANSYS finite element code work and again is well along. One area where further work is needed is safety during quench. This requires further clarification of the MECO requirements and specifications and then analysis, particularly of quench pressures in the vessels. With that one exception, the analysis is nearly complete and the committee recommends that the design team begin the task of transforming the analysis details into specifications that can become part of the Technical Spec.

b. Technical issues addressed in an appropriate priority. In general, the CDR is following the accepted practice of first establishing the electromagnetic design then the coil structural design, vessel design and cryogenics. This is an iterative process. Also, to date, the coils that have received the most attention are the PS and TS, as they are clearly the most challenging.

c. Design study proceeding toward a conservative approach. The coil designs presented are constrained by two factors, the main one being the use of surplus SSC conductor. The other factor is the somewhat arbitrary pre-selection of the magnet design criteria:

1. $I/I_c < 0.65$
2. $T_{op} < T_{cs}$ - 0.75 K
3. $V_D < 2$ kV
4. $T_{max} < 150$ K

These factors have led the MIT/PFSC group to design a coil set based on a fully potted winding. Although this approach has merit, it leads to concern particularly for the PS, which experiences significant nuclear heating and the TS, which has substantial non-axisymmetric forces. There is a possibility that following this approach could lead to training or spontaneous quenching of the MECO magnets. A more conservative approach would involve a thermal stability level that cannot be achieved with a potted winding. See comments below regarding use of surplus SSC cable.

d. Design built by industrial concern. The committee feels that the MECO magnet system can and should be built in industry. The design is rather similar to other magnet systems built in the past and the industrial infrastructure exists in several locations in the US and abroad. See comments below regarding procurement strategy.

e. Cost and time savings through the use of SSC surplus equipment. The design study has focused its attention on conductor designs that use SSC cable (inner in the PS and outer in the TS and DS). To date, there has not been much effort applied to other options. This narrowed approach is probably unwise at such an early stage in the project. The cost savings associated with use of the SSC cable (probably < $1M), may not outweigh the added risk of the potted winding and associated down time should the magnet require training or experience periodic quenches.

f. The use of SSC surplus refrigerators may be appropriate as BNL has such equipment on site and plans to incorporate the MECO operation as part of the BNL cryogenics operations.

2. Structure for the interaction between the MECO Collaboration, BNL, and the Magnet Design Group (MDG).

There appears to be good communication between the three groups. However, there were several issues about which the committee expressed concern. Although the presentations covered the range of magnet design issues, the committee believes there needs to be a clear set of requirements and specifications for the MECO experiment and more specifically the MECO magnet system. Since this was an interim review and the activities thus far have correctly concentrated on analysis, the only drawings shown were those produced during the course of analysis - not true engineering drawings. Now that a good analysis foundation is in place, efforts during the remaining three months of the study should move very strongly to the tasks of developing the requirements, specifications, and drawings to give the MECO project the technical basis needed to move on to the procurement stage as planned. It is recommended that the coil lead areas – the most frequent areas of failure in magnets- be given appropriate emphasis in both the drawings and requirements. A clearer statement of what constitutes a system requirement versus design decision/options would be a benefit to future committee reviews.

In addition, there needs to be a clearer indication of the interface between the BNL facilities and staff and the MDG. . At present, BNL has very limited funding to support MECO. More funding for BNL now may prove to be beneficial in resolving interface issues early on. This detail needs to be resolved before the final design and procurement gets underway.

3. Various MECO procurement strategies. Three procurement strategies were presented to the committee. These were:

> a. A procurement contract from a Non-Profit Organization (assumed BNL) to a company or group of companies for a fixed price performance guarantee.
>
> b. A procurement contract as in (a) for a cost plus fixed (or incentive) fee.
>
> c. A subcontract to non-profit organization for detailed engineering design and system integration, with acquisition of sub-components from industry through subcontracts.

The committee was told that strategies a or b would be carried out by BNL procurement and property management under an agreement between NSF, MECO and the Laboratory. We were not asked to comment on this approach. Of the three options discussed, the committee did not believe that option (a) would be feasible without very high cost or no qualified bidders willing to accept the risk. Since the MECO magnet system is one-of-a-kind, the interested industries will need to fully recover their costs. Option (c) may also be undesirable because it would be difficult to control costs associated with engineering design and assembly. Option (b) therefore appears most attractive.

It was further recommended that MECO follow a two-step process for solicitation and qualification of potential vendors for the magnet system. This approach is based on experience at the Princeton Plasma Physics Lab (PPPL). At completion of the CDR and technical specification documents, MECO should host a meeting for potential industrial bidders. MECO would then decide to issue a limited number (2 or 3) of small contracts (about $25k each) for manufacturing studies. The deliverables for these studies would include design and materials recommendations to improve manufacturability, suggestions for R&D and prototype activities aimed at reducing uncertainties and developing the confidence for the manufacturing phase, and budgetary cost estimates for manufacture. This would ensure a serious effort on the part of the industrial concern. It would also encourage the industries to become better acquainted with MECO so that their bids would more accurately predict true project costs. This approach would be particularly attractive if there were incentive fees built into the final contract. The committee believes that this approach would produce the best quality product at minimum cost. It may also be necessary to include some cost controlling incentive in the final contract.

Specific areas of concern and other comments:

1. Consideration should be given to using a ventilated winding or cable-in-conduit conductor at least for the PS and possibly for the TS. Indirect cooling such as a natural circulation loop may be appropriate for the DS.

2. Consideration should be given to alternative structural approaches for the PS, which would avoid the difficult and costly shrink fit outer cylinder. For example, ribbed aluminum plates could be positioned around the winding to provide cooling on the OD, with the plates banded with a “dummy winding”, fiberglass-epoxy or carbon fiber-epoxy to provide the required hoop stress reinforcement.

3. The maximum current density requirements appear to be arbitrary. For potted windings, I/I_c is often less than 50%. Some justification for the selected value based on similar successful magnet systems should be given.

4. The issue of discharge voltage, turn-to-turn insulation and ground plane insulation needs further consideration.

5. Quench safety needs to be evaluated. A design pressure for the various cryogenic vessels is needed based on worst-case analysis.

6. The structural design of the transport solenoids is of concern. Options should be considered to reduce the number of bolts and number of seal welds between vessels. The design presented has separate coil structures (which also serves as the winding form) for each coil. These are then structurally joined together by bolts and welds after the windings are installed to form the TS assembly. An alternative which should be

considered is to make the structure in 3-4 segments, with each segment accommodating several windings. This approach would greatly reduce the number of bolts and welds at assembly. It would also provide more space to access these bolt and weld areas.

7. Alternate cooling schemes should be considered for the TS and detector solenoids. Since the heat loads for these magnets are low, they can be adequately cooled by conduction to cooling panels around the periphery of the magnets.

8. Some consideration should be given to designing the system for possible repairs. These may include replacement of specific coils or other functional parts within the vessels.